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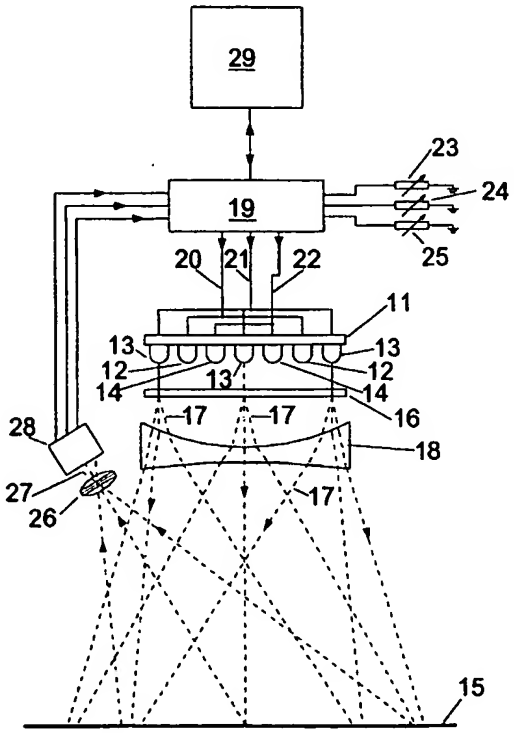

(57) Abstract: Apparatus and a corresponding method for the diagnosis and alleviation of symptoms of visually induced physiological defects and/or pathological conditions is provided. A plurality of narrow-band light sources are combined to constitute a colour controllable lamp. A method for adjusting the settings of this lamp permits the optimum illumination for a particular subject to be found, whilst the latter carries out a task such as reading or writing. By use of the lamp to simulate the expected visual stimulus, to which the subject would be exposed if provided with viewing aids such as tinted spectacles and the like, an optimal selection from a database of such aids may be made or a new formulation defined. Inter alia, the symptoms of visual dyslexia, macular generation and visually induced migraine may be alleviated.

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APPARATUS AND METHOD FOR ALLEVIATION OF SYMPTOMS BY APPLICATION OF TINTED LIGHT

The current invention is concerned with the provision or filtration of the illumination for a given task, such as reading or writing, and, specifically, with helping to alleviate the symptoms of certain physiological defects, such as dyslexia, or pathological conditions, such as migraine or macular degeneration, which may be suffered by the subject undertaking the task.

BACKGROUND

It is known that the response of the visual system is affected by the stimuli, which it receives. The threshold for such stimulation varies between individuals and, under adverse conditions, can significantly reduce performance. When the visual system is over stimulated, it reacts in a number of ways. Amongst a variety of undesirable effects, which can be caused, two examples include a drop in convergence sufficiency and a reduction in the ability to accommodate or fuse images. In addition, visual dyslexia may become apparent and migraines can be caused. Visual dyslexia is a condition of impaired reading and writing ability due to visual perception or visualisation problems. It is apparent therefore that for some it is necessary to modify the visual stimulus by changing the spectral distribution in a specific task e.g. reading and writing in school. In summary, it is well established that the colour of ambient lighting has a major influence on the effects of disorders such as dyslexia, epilepsy and migraine. In the case of dyslexia some sufferers can alleviate their reading problems by covering the page with a transparent coloured overlay in order to block out those wavelengths of light which give rise to an aspect of their problem. These overlays typically remove various amounts of simple primary colours, such as red, green or blue light and whilst they may assist with reading, they are of no value for writing.

In US Patent No. 5,855,428 (Wilkins) apparatus is described in which the spectral distribution of light from a fluorescent lamp to illuminate a surface to support reading material is altered by the interposition of specifically selected broadband filters. By adjustment of the position of the selected filter or filters different colours and saturation thereof can be selected.

In US Patent Application No 2001/0005319 A1 (Ohishi et al.) an illumination control system, for general use, is described, in which the coordinates in colour space of the

controlled illumination are arranged to follow a predetermined locus of points by mixing specific amounts of light from a plurality of differently coloured light emitting diodes (LED's).

Neither of these documents identifies the benefit of using sources which are characterised by providing light with a spectral distribution which is relatively narrow for application to the alleviation of the symptoms of the physiological defects and/or pathological conditions identified herein. This would be the case for laser sources, super-luminescent LED's and conventional coloured LED's, which provide light with a typical spectral bandwidth of between 17 nm to around 50 nm. The provision of illumination using additive light sources, such as LED's for the quantitative diagnosis and alleviation of the symptoms identified is the subject of this invention.

SUMMARY OF THE INVENTION

It is an object of the current invention to provide optimal illumination for an observer who may be suffering from physiological defects or pathological conditions of his/her visual system in order to alleviate the symptoms thereof.

It is a further object of the current invention to provide a means for specifying a colour formulation for the lenses of the spectacles to be worn by a patient suffering from one or more of the aforesaid physiological defects or pathological conditions.

Using a specific controllable light source for a particular task can be preferable to other forms of treatment (e.g. tinted spectacles), as the task lighting can be tailored precisely, for example to take account of the ambient conditions. A specific light is also of particular importance in certain eye conditions such as macular degeneration or cataract as optimum performance is directly related to visual stimulus input, particularly if the person has relatively poor vision. Specific stimulus modification will also be of great use in migraine prevention and treatment with possible uses in attention deficit hyperactivity syndrome and some types of epilepsy. Where it is desirable for the subject to use tinted spectacles, a controllable light source, as described herein, is a useful tool for defining the preferred filter characteristics of the tinted lenses.

Thus, according to one aspect of this invention means is provided for the quantitative diagnosis and/or alleviation of the symptoms of a plurality of visually induced physiological defects and/or pathological conditions suffered by an observer comprising a plurality of light sources, each of which is arranged to emit a respective

spectral component of the visible spectrum, and control means for selecting a weighted mixture of said spectral components to provide illumination, characterised in that, in use, said illumination is arranged to illuminate a surface for viewing by the observer; said mixture is an additive combination of the spectral components emitted by at least two of said light sources; and the control means provides the means for varying the amount of illumination from each of said at least two light sources to impinge on said surface whereby, in use, a combination of said spectral components is provided to alleviate the symptoms of at least one of said visually induced physiological defects and/or pathological conditions.

The physiological defect may be visual dyslexia, visually induced migraine or macular degeneration.

Preferably a spectral component has a dominant wavelength which contributes to a respective first tristimulus value of the light entering an eye of the observer whilst substantially maximising the ratio of said contribution to said first tristimulus value to the root mean square of the contributions by said dominant wavelength to each of the second and third tristimulus values of the light entering the eye of the observer.

Advantageously, a first spectral component may comprise a dominant wavelength located between 465 nm and 475 nm. Another spectral component may comprise a dominant wavelength located between 520 nm and 530 nm. A third spectral component may have a dominant wavelength in the range 610 nm and 650 nm.

In preferred embodiments of the invention each light source comprises at least one light emitting diode arranged to provide one of the spectral components. Preferably a spectral component has a spectral power distribution having a width at half height which does not exceed 50 nm.

Advantageously, the illumination from each of the light sources is diffused prior to impinging on the viewed surface so that the relative intensity of the light impinging at two points spaced on said surface is substantially the same for each of said spectral components.

According to a further aspect of the invention means is provided for computing the combined effect of at least two of the active illumination spectra, the ambient illumination spectrum, the reflectance spectrum of the target or an illuminated

surface, the transmission spectrum of at least one filter and the transmission spectrum of a surface coating over the visible spectrum, so that in use, the subject's retinal response may be predicted and the settings of the active light source and/or the formulation of a filter to be used by the subject may be optimised.

According to another aspect of the invention, a method for the diagnosis of a plurality of visually induced physiological defects and/or pathological conditions suffered by a subject comprises arranging a plurality of light sources to emit different spectral components within the visible spectrum, characterised by implementing the successive steps of:-

(a) assessing the subject's performance with a series of targets under different levels of each of a plurality of illuminants, comprising individual spectral components or pre-determined ratios thereof,

(b) recording the optimum level of each of said illuminants and

(c) combining the levels of each respective illuminant as recorded in step (b) to provide a resultant additive mix of said illuminants.

Preferably, the method includes the further step of applying variations to the level of each of the spectral components in small steps whilst combined in order to establish the mix of said illuminants which substantially optimises the subject's performance.

According to yet another aspect of the invention a method for simulating the performance of a selected filter comprises the steps of:-

(a) defining the tristimulus values of the tint which would be observed by an observer when said filter is used in transmission for viewing a reading surface

(b) providing a colour controllable lamp comprising narrow band coloured light sources

(c) illuminating the reading surface for viewing by the observer with said lamp and

(d) selecting the level of illumination provided by each light source so that, in use, the defined tristimulus values are observed by the observer.

Preferably the method includes the step of simulating a range of pre-formulated filters and lighting conditions, whereby the observer can select one or more filters for use under said conditions. and the method includes the further step of formulating and/or selecting the filter to optimise the observer's performance.

The invention permits the formulation of filters and/or anti-reflection coatings for spectacles, contact lenses, coloured overlays or any other tinted material a purpose of which is to alleviate problems caused by colour related disorders of the human visual system.

DESCRIPTION OF PREFERRED EMBODIMENTS

The invention will now be described with reference to Figures 1a to 4 in which:-

Figure 1a illustrates the response of the human visual system, as a function of the wavelength of the light incident thereon. Additional curves are provided to aid in the description of the invention.

Figure 1b provides further curves showing the sensitivity characteristics of the colour receptors or cones at the human retina.

Figure 2 illustrates, diagrammatically, apparatus constructed in accordance with the invention in order to provide a colour controllable source of illumination,

Figure 3 shows in flowchart form a preferred method in accordance with the invention for use of the apparatus of Figure 2

Figure 4 shows the transmission spectrum of a typically tinted lens, formulated to reduce the relative stimulus to one type of cone, in accordance with the invention.

Figure 1a shows the so-called spectral tristimulus values as a function of wavelength λ. These curves, which represent the amounts of idealised primaries required to match any of the pure spectral colours in the visible range and are related to the colour sensitivity characteristics of the human eye. Curve 1, typically designated as the function $\bar{x}(\lambda)$, primarily comprises the responsivity of the red sensitive cones of the human retina. The blue sensitive cones' responsivity is, suitably scaled, also included in this first tristimulus

curve (see Figure 1b). Curve 2 is, to a good approximation, a summation of the green and red cones' responsivity curves and is designated as the function $\bar{y}(\lambda)$ and actually corresponds to the overall spectral sensitivity of the eye. Curve 3 essentially comprises the blue cones' spectral sensitivity characteristic $\bar{z}(\lambda)$. It will be clear from these curves that the $\bar{x}(\lambda)$ curve has a subsidiary maximum in the blue region of the visible spectrum. A colour stimulus to the human visual system may be conveniently expressed as three values, the so-called tristimulus values (X, Y and Z), each of which involves an integral over the visible spectrum of the spectral power distribution reaching the retinal cones convolved with the respective tristimulus curve. For example:-

$$X = \int_{\lambda} P(\lambda)\bar{x}(\lambda)d\lambda$$

Two further sets of curves are shown in Figure 1a. One of these comprises dashed lines 4 and 5. Line 4 represents, following some normalisation, the ratio between $\bar{z}(\lambda)$ and the root mean squares of $\bar{x}(\lambda)$ and $\bar{y}(\lambda)$ and line 5 represents, on the same basis, the ratio between $\bar{y}(\lambda)$ and the root mean squares of $\bar{x}(\lambda)$ and $\bar{z}(\lambda)$.

The objective in calculating these functions is to find those points within the visible spectrum where the effect of the resultant stimulus of the human visual system is substantially expressed as a change to one of the tristimulus values, with the change to the other two being minimised relative thereto. What the two curves show is that, for a maximum change to Z relative to X and Y, stimulation of the human visual system at a wavelength of around 470 nm should be used and that, for maximum change of Y relative to X and Z, stimulation of the human visual system at a wavelength of around 520 nm is most effective. There is no clear choice for X , but a wavelength of around 640 nm is found to achieve good red saturation without too much loss of overall sensitivity.

It is an objective of this invention to provide a means for controlling the colour stimulation of the human visual system, so that an optimum ratio of X, Y and Z values can be established. When this is achieved, the visual or related disability and/or symptom of the subject, experienced under normal illumination, can be substantially alleviated. It will be clear that a combination of controllable narrow-band light sources, located respectively at substantially 470 nm, 520 nm and, say, 640 nm, will readily achieve this goal. All of these wavelengths are substantially achieved with commercially available LED's, the bandwidths of which typically vary from 17 nm to 47 nm. Typical examples

of such emitted spectra are shown in Figure 1a as curve 6, for Z, peaking at 470 nm (defined as blue herein), curve 7, for Y, peaking at 524 nm (defined as green herein) and curve 8, for X, peaking at around 640 nm in the red portion of the spectrum. The red wavelength is not as critical as the other two, for the reasons stated above.

By combining the light from the three different types of LED, as specified above, a wide range of tints can be achieved. A lamp comprising one or more of each type of LED, arranged in a variety of different ways, in which each group of a specific colour is controlled by an adjustable signal, can be used to optimise the illumination for a given subject carrying out a specific task, such as reading or writing. For example, a person who suffers from dyslexia may have a reading difficulty significantly alleviated by the partial or complete exclusion of the red illumination, in effect, by reducing the stimulation of the red sensitive cones.

Embodiments of the current invention use a multi-colour light emitting diode (LED) array, operated within an optical assembly so that colours can be mixed to create the optimum lighting for any patient. An array of different coloured LEDs, typically red, green and blue, in accordance with the principles outlined above are operated either individually or together, so that it is possible to select single primary colours or combine the various LEDs to give different hues and illuminance. The primary advantage with this type of lighting being that it can be used for both reading and writing.

A colour selectable lamp allows much greater flexibility and the opportunity to suit the lighting to each user. This could have important applications in the office and school environment where ambient lighting limitations contribute to reading and writing problems for some individuals.

Turning to Figure 2, this shows diagrammatically how a number of components may be combined in accordance with the principles of the invention to form a colour controllable light source.

An array of LED's 11 is comprised of red emitters 12, having an emission spectrum peaking at 640 nm, green emitters 13, having an emission spectrum peaking at 524 nm, and blue emitters 14, having an emission spectrum peaking at 470 nm. The LED's are distributed in such a manner that the field illuminated by each type at a reading surface 15 is approximately the same. In order to ensure that there are no substantial differences in the mix of colours at any given point on the reading surface, a diffuser 16 is placed in

the path of the emitted light. This diffuser may take several different forms. A lenticular screen or microlens array is found to be effective, as well as other kinds of efficient light scattering media. For example, a material comprising changes of refractive index over short distances can be very effective.

The effect of distributing the individual LED's in an even manner, together with the action of the diffuser 16, is to provide a very even mix of light at the reading surface 15. In order to extend the effective area of illumination, a divergent lens assembly 18 can be very useful. Although this is shown as a conventional meniscus lens, a compact equivalent, such as a fresnel lens may also be used.

A control unit 19 receives a number of different inputs, prior to driving each group of LED's via outputs 20 for blue, 21 for green and 22 for red. At its simplest level, variable resistors 23, 24 and 25 are used to set the light output from the red, green and blue LED's respectively. The components identified, thus far, comprise a colour controllable lamp. This can be used by a subject to select a particular combination of red, green and blue illuminants, which is optimal for his or her reading or writing performance.

In practice, a more sophisticated version of such a lamp would adapt the light output demanded from the LED array to take account of the ambient conditions. In Figure 2 a lens 26 forms an image on the receiving surface 27 of a camera 28. This may be a CCD or other photo-detector array, behind a colour filter array. Using known principles, the video signal from the CCD can be analysed to provide a reading of the level of illumination at surface 15, in addition to its colour mix. There will be a specific matrix, which will allow the measure of light passing through each component of the camera's colour filter array to be translated into a red, green and blue LED light combination. Some of this will be contributed by the ambient light impinging on surface 15. The output, required from each type of LED, is adjusted by control unit 19, accordingly. As a consequence of the use of camera 28 to monitor the illumination of surface 15 the resulting system will also be stabilised against other variations, such as changes in the efficiency of the optics or LED's.

The apparatus of Figure 2 can be very useful as a diagnostic tool, particularly when used in conjunction with a computer, shown as block 29. Inter alia, the computer can be used to store the selected tint of the illumination at surface 15, when this has been optimised for the subject.

Turning to Figure 3, this outlines, in summary form, a methodology in accordance with the invention for establishing the optimal illumination for a specific subject, such as, for example, a person suffering from visual dyslexia.

The first step in the procedure is to determine the best illumination conditions for a variety of different reading tests. This is done by illuminating the reading material at surface 15 of Figure 2 with one of the illuminants. This is increased in brightness, until the subject is satisfied that the optimal brightness has been found. It may be necessary to pass through the optimum and to reduce the brightness slightly to establish that setting. This step is repeated for each of the illuminants (LED groups), separately. It is quite possible that the optimum level for the red illumination may be at 50% of maximum, for a particular subject, whereas the green and blue illuminants would be quite acceptable at their maximum levels. The particular settings for each illuminant will be highly subject dependent. Step 2 is to record the optimum level for each illuminant, either directly from the controls or transferred automatically to a computer.

Once the individual optima have been established, the recorded levels of each primary illuminant are combined in Step 3 of the procedure. Step 4 is to fine tune this mixture by making small adjustments to each primary (red, green and blue), in small steps, until an optimum mix is established for the subject. The step changes would be made in both directions, decreasing or increasing the particular illuminant, and establishing whether there is an improvement or otherwise in the subject's performance. By iteration of Steps 3 and 4, the best combination is found.

One of the key objectives of this invention is to use the arrangement of Figure 2 as a diagnostic tool, in order to arrive at an optimal formulation for the filters to be provided for the lenses of spectacles or contact lenses to be worn by the subject. The colour of the light reaching the subject's eyes is recorded by the system of Figure 2 and stored in computer 29. This record will typically contain information about the settings of the LED sources and, if any, the colour and level of the ambient illumination at the time that the measurements were made. By prior knowledge or use of colour camera 28, any colouration of the reading surface 15 may also be accommodated.

In practice there will be a finite selection of filter formulations available. A typical filter characteristic is shown in Figure 4. Curve 41 represents the percentage transmission of a red absorbing (blue tinted) filter as a function $T(\lambda)$ of the wavelength λ of the light

incident upon it. Our interest is in knowing what the response at the retina of each eye will be for each of the cones when the subject views material through this filter. In order to calculate this we must multiply each of the tristimulus curves at every wavelength with the spectral distribution of the light arriving at the retina and integrate this result over the visible spectrum. The result will be one of the tristimulus values for the particular tint, as defined by the CIE 1931 chromaticity diagram. It will comprise a number of components, including the following:-

1) the spectrum of the illumination which the subject will use when reading or writing (This could be daylight or light from a tungsten or fluorescent lamp and each will have a different spectrum),

2) the background reflectance spectrum of the material being read and

3) the relevant tristimulus curve.

For the response corresponding to each of the tristimulus values the integral required will be of the form

$$X = \int_{380nm}^{780nm} I(\lambda)T(\lambda)R(\lambda)\bar{x}(\lambda)d\lambda,$$

Where I(λ) is the illumination spectrum, T(λ) is the filter's transmission spectrum, R(λ) is the illuminated substrate's reflectance spectrum and $\bar{x}(\lambda)$ is the relevant tristimulus curve, curve 1 in Figure 1a. Two further integrals would be calculated for the Y and Z tristimulus values.

It will be clear to those versed in the art that the same tristimulus values can be achieved with a different illumination spectrum and, in principle, without the use of the intervening transmission filter. Indeed, where the illumination spectrum is comprised of the combination of the three primary illuminants provided by the red, green and blue LED's of Figure 2, this spectrum will have three well-defined peaks. As already explained, by reference to Figure 1a and Figure 1b, each of these peaks will have a particularly significant influence on only one of the tristimulus values.

It is a further objective of this invention to simulate the effect of any particular filter by providing illumination which simulates the effect on the visual system that would result from the use of that filter under the expected lighting conditions. Thus the LED outputs, with the reflectance characteristics of the reading surface 15 in Figure 2 being taken into

account, must be adjusted to simulate that part of the function under the integral above represented by $I(\lambda)T(\lambda)R(\lambda)$. In effect, $I(\lambda)T(\lambda)$ will be replaced by the following expression:-

$$E(\lambda) = rR(\lambda)+gG(\lambda)+bB(\lambda),$$

where r, g and b represent the components of each of the primary illuminants and $R(\lambda)$, $G(\lambda)$ and $B(\lambda)$ are the respective spectral power distributions of these, as shown in Figure 1a as curves 8, 7 and 6 respectively.

For every choice of filter characteristic available there will be values of r, g and b which will simulate the effect for the subject under a particular selection of lighting. Having established an optimal tristimulus value for the subject by using the procedure of Figure 3, a best choice of tint may be selected or formulated. A database of all standard filters may be held on computer 29, in order to provide a convenient method for prescribing an available choice of filter. The precise effect of that filter being available for the subject to experience by simulation using the apparatus of Figure 2

It follows from this that the apparatus of Figure 2 may be used to determine the relative colour response of an individual's eye. In this case a surface of known colour reflectance is made to look white by adjusting r, g and b values above. The expression describing this is:

$$CC[surface(\lambda) * (E_r(\lambda)*rR(\lambda)+E_g(\lambda)*gG(\lambda)+E_b(\lambda)*bB(\lambda))] = CC_p$$

where $CC[f(\lambda)]$ is the colour co-ordinate transformation of a spectrum, CC_p is the perceived white colour response and $E_r(\lambda)$, $E_g(\lambda)$ and $E_b(\lambda)$ are the eye responses. For a known surface and instrument settings and a normal eye response then the perceived white colour will correspond with the actual colour co-ordinates of white with CC_p = [0.33,0.33,0.33].

For an eye with a different colour response CC_p will be at a different position in colour space and the vector between this position and nominal white will be a measurement of relative colour response of the eye.

By further reference to Figure 1a it also follows that, in order to reduce the X tristimulus value to a minimum, a light source with its energy concentrated at around 505 nm is required. Such a facility may prove particularly useful in circumstances where the

function of the lamp is a diagnostic one and a complete absence of the X stimulus is desired.

Although the embodiment of Figure 2 incorporates a divergent lens to spread the illumination over the desired area, this is not an essential component for the operation of the lamp, as the combination of a diffuser and suitably positioned LED's can be chosen to illuminate any specific area. Whilst the embodiments illustrated herein utilise LED's with relatively narrow-band emission spectra, other devices such as laser sources may be used as alternative illuminants. Furthermore, whereas a camera 28 is employed to analyse the colour of the illumination of surface 15, this could, in practice, be replaced by a series of photodiodes receiving light from this surface through suitable colour filters.

CLAIMS

1. Apparatus for the quantitative diagnosis and/or alleviation of the symptoms of a plurality of visually induced physiological defects and/or pathological conditions suffered by an observer comprising a plurality of light sources, each of which is arranged to emit a respective spectral component of the visible spectrum, and control means for selecting a weighted mixture of said spectral components to provide illumination, characterised in that, in use, said illumination is arranged to illuminate a surface for viewing by the observer; said mixture is an additive combination of the spectral components emitted by at least two of said light sources; and the control means provides the means for varying the amount of illumination from each of said at least two light sources to impinge on said surface whereby, in use, a combination of said spectral components is provided to alleviate the symptoms of at least one of said visually induced physiological defects and/or pathological conditions.

2. Apparatus as claimed in Claim 1 in which the physiological defect is visual dyslexia.

3. Apparatus as claimed in Claim 1 in which the pathological condition is visually induced migraine.

4. Apparatus as claimed in Claim 1 in which the pathological condition is macular degeneration.

5. Apparatus as claimed in Claim 1 in which a spectral component has a dominant wavelength which contributes to a respective first tristimulus value of the light entering an eye of the observer whilst substantially maximising the ratio of said contribution to said first tristimulus value to the root mean square of the contributions by said dominant wavelength to each of the second and third tristimulus values of the light entering the eye of the observer.

6. Apparatus as claimed in Claim 5 in which a first spectral component comprises a dominant wavelength located between 465 nm and 475 nm.

7. Apparatus as claimed in Claim 5 in which a first spectral component comprises a dominant wavelength located between 520 nm and 530 nm.

8. Apparatus as claimed in Claim 6 in which a second spectral component comprises a dominant wavelength located between 520 nm and 530 nm.

9. Apparatus as claimed in any of claims 6 to 7 which includes a spectral component having a dominant wavelength in the range 610 nm and 650 nm

10. Apparatus as claimed in claim 1 in which each of said light sources comprises at least one respective light emitting diode arranged to provide one of said spectral components.

11. Apparatus as claimed in claim 5 in which a spectral component has a spectral power distribution having a width at half height which does not exceed 50 nm.

12. Apparatus as claimed in claim 1 in which the illumination from each of the light sources is diffused prior to impinging on the surface so that the relative intensity of the light impinging at two points spaced on said surface is substantially the same for each of said spectral components.

13. Apparatus as claimed in claim 1 further comprising means for computing the combined effect of at least two of the active illumination spectra, the ambient illumination spectrum, the reflectance spectrum of the target or an illuminated surface, the transmission spectrum of at least one filter and the transmission spectrum of a surface coating over the visible spectrum, so that in use, the subject's retinal response may be predicted and the settings of the active light source and/or the formulation of a filter to be used by the subject may be optimised.

14. A method for the diagnosis of a plurality of visually induced physiological defects and/or pathological conditions suffered by a subject which comprises arranging a plurality of light sources to emit different spectral components within the visible spectrum, characterised by implementing the successive steps of:-

(a) assessing the subject's performance with a series of targets under different levels of each of a plurality of illuminants, comprising individual spectral components or pre-determined ratios thereof.

(b) recording the optimum level of each of said illuminants

(c) combining the levels of each respective illuminant as recorded in step (b) to provide a resultant additive mix of said illuminants

15 The method of Claim 14 including the further step of applying variations to the level of each of the spectral components in small steps whilst combined in order to establish the mix of said illuminants which substantially optimises the subject's performance.

16 A method for simulating the performance of a selected filter which comprises the steps of:-

(a) defining the tristimulus values of the tint which would be observed by an observer when said filter is used in transmission for viewing a reading surface

(b) providing a colour controllable lamp comprising narrowband coloured light sources

(c) illuminating the reading surface for viewing by the observer with said lamp and

(d) selecting the level of illumination provided by each light source so that, in use, the defined tristimulus values are observed by the observer.

17 The method of claim 16 further comprising the step of simulating a range of pre-formulated filters and lighting conditions, whereby the observer can select one or more filters for use under said conditions.

18 The method of claim 16 or claim 17 which includes the further step of formulating and/or selecting the filter to optimise the observer's performance.

19 A method as claimed in any one of claims 16 to 18 applied to the formulation of filters and/or anti-reflection coatings for spectacles, contact lenses, coloured overlays or any other tinted material a purpose of which is to alleviate problems caused by colour related disorders of the human visual system.

20 A method for the alleviation of the symptoms of a plurality of visually induced physiological defects and/or pathological conditions suffered by an observer which comprises arranging a plurality of light sources to emit different spectral

components within the visible spectrum, and controlling the weight of each of said spectral components to provide illumination, characterised by arranging at least two of the light sources to additively illuminate a surface for viewing by the observer; varying the amount of illumination from each of said at least two light sources to impinge on said surface; and providing a combination of said spectral components to alleviate the symptoms of at least one of said visually induced physiological defects and/or pathological conditions.

AMENDED CLAIMS
[received by the International Bureau on 06 June 2002 (06.06.02);
original claims 1-20 replaced by amended claims 1-17 (3 pages)]

1. Apparatus for the quantitative diagnosis and/or alleviation of the symptoms of a plurality of visually induced physiological defects and/or pathological conditions suffered by an observer comprising a plurality of light sources, each of which is arranged to emit a respective spectral component of the visible spectrum, and control means for selecting a weighted mixture of said spectral components to provide illumination, characterised in that a spectral component has a dominant wavelength which contributes to a respective first tristimulus value of the light entering an eye of the observer whilst substantially maximising the ratio of said contribution to said first tristimulus value to the root mean square of the contributions by said dominant wavelength to each of the second and third tristimulus values of the light entering the eye of the observer.

2. Apparatus as claimed in Claim 1 in which the physiological defect is visual dyslexia.

3. Apparatus as claimed in Claim 1 in which the pathological condition is visually induced migraine.

4. Apparatus as claimed in Claim 1 in which the pathological condition is macular degeneration.

5. Apparatus as claimed in Claim 1 in which, in use, said illumination is arranged to illuminate a surface for viewing by the observer; said mixture is an additive combination of the spectral components emitted by at least two of said light sources; and the control means provides the means for varying the amount of illumination from each of said at least two light sources to impinge on said surface whereby, in use, a combination of said spectral components is provided to alleviate the symptoms of at least one of said visually induced physiological defects and/or pathological conditions.

6. Apparatus as claimed in Claim 1 in which a first spectral component comprises a dominant wavelength located between 465 nm and 475 nm.

7. Apparatus as claimed in Claim 1 in which a first spectral component comprises a dominant wavelength located between 520 nm and 530 nm.

8. Apparatus as claimed in Claim 6 in which a second spectral component comprises a dominant wavelength located between 520 nm and 530 nm.

9. Apparatus as claimed in any of claims 6 to 7 which includes a spectral component having a dominant wavelength in the range 610 nm and 650 nm

10. Apparatus as claimed in claim 1 in which each of said light sources comprises at least one respective light emitting diode arranged to provide one of said spectral components.

11. Apparatus as claimed in claim 1 in which a spectral component has a spectral power distribution having a width at half height which does not exceed 50 nm.

12. Apparatus as claimed in claim 1 in which the illumination from each of the light sources is diffused prior to impinging on the surface so that the relative intensity of the light impinging at two points spaced on said surface is substantially the same for each of said spectral components.

13. Apparatus as claimed in claim 1 further comprising means for computing the combined effect of at least two of the active illumination spectra, the ambient illumination spectrum, the reflectance spectrum of the target or an illuminated surface, the transmission spectrum of at least one filter and the transmission spectrum of a surface coating over the visible spectrum, so that in use, the subject's retinal response may be predicted and the settings of the active light source and/or the formulation of a filter to be used by the subject may be optimised.

14 A method for the diagnosis of a plurality of visually induced physiological defects and/or pathological conditions suffered by a subject which comprises arranging a plurality of light sources to emit different spectral components within the visible spectrum, characterised by implementing the successive steps of:-

a) assessing the subject's performance with a series of targets under different levels of each of a plurality of illuminants, comprising individual spectral components or pre-determined ratios thereof.

b) recording the optimum level of each of said illuminants

c) combining the levels of each respective illuminant as recorded in step (b) to provide a resultant additive mix of said illuminants

15 The method of Claim 14 including the further step of applying variations to the level of each of the spectral components in small steps whilst combined in order to establish the mix of said illuminants which substantially optimises the subject's performance.

16 A method for simulating the performance of a selected filter which comprises the steps of:-

(a) defining the tristimulus values of the tint which would be observed by an observer when said filter is used in transmission for viewing a reading surface

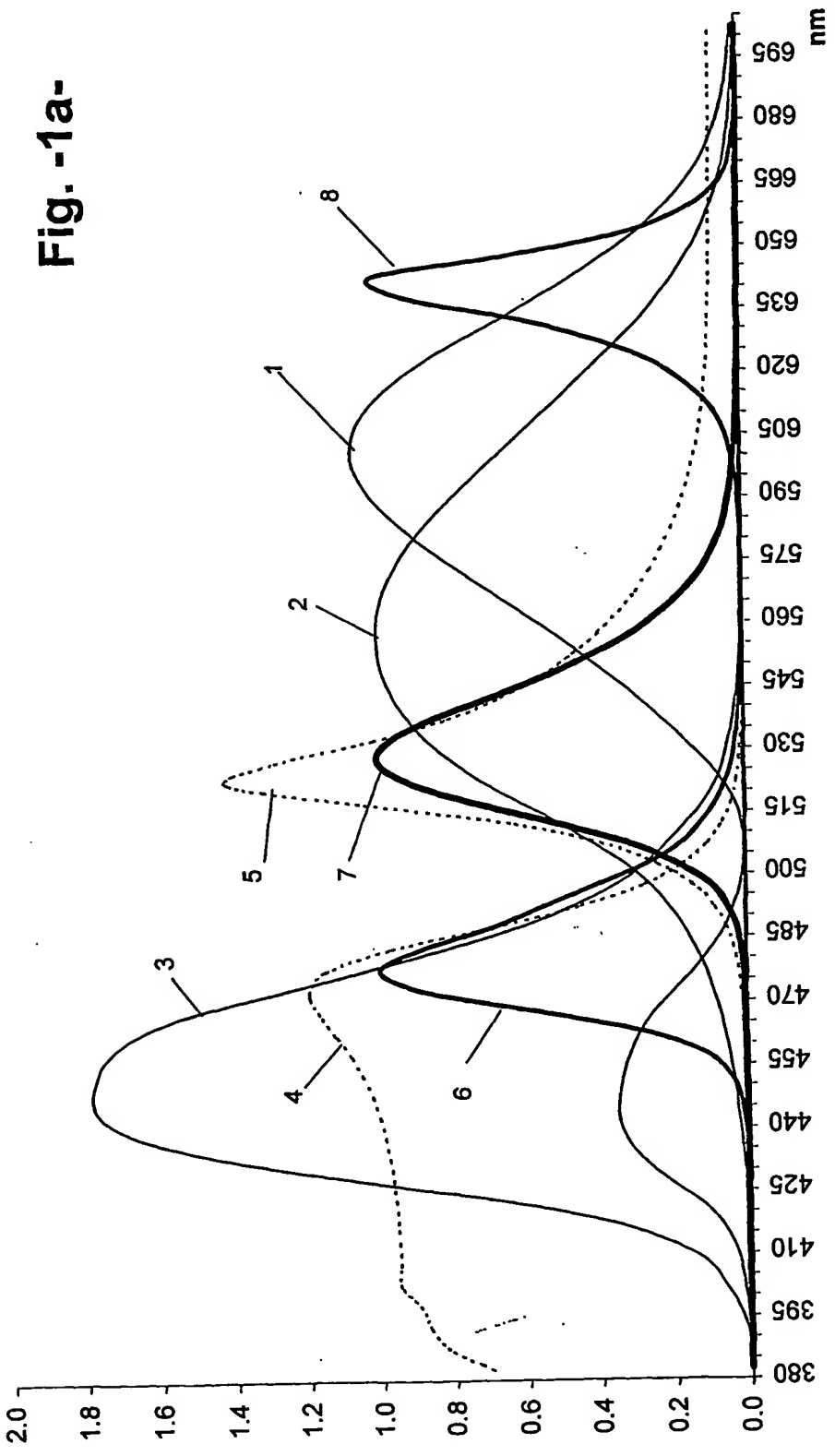
(b) providing a colour controllable lamp comprising narrowband coloured light sources

(c) illuminating the reading surface for viewing by the observer with said lamp and

(d) selecting the level of illumination provided by each light source so that, in use, the defined tristimulus values are observed by the observer.

17 The method of claim 16 further comprising the step of simulating a range of pre-formulated filters and lighting conditions, whereby the observer can select one or more filters for use under said conditions.

Fig. -1a-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665
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395
380
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1.6
1.4
1.2
1.0
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0.4
0.2
0.0
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2
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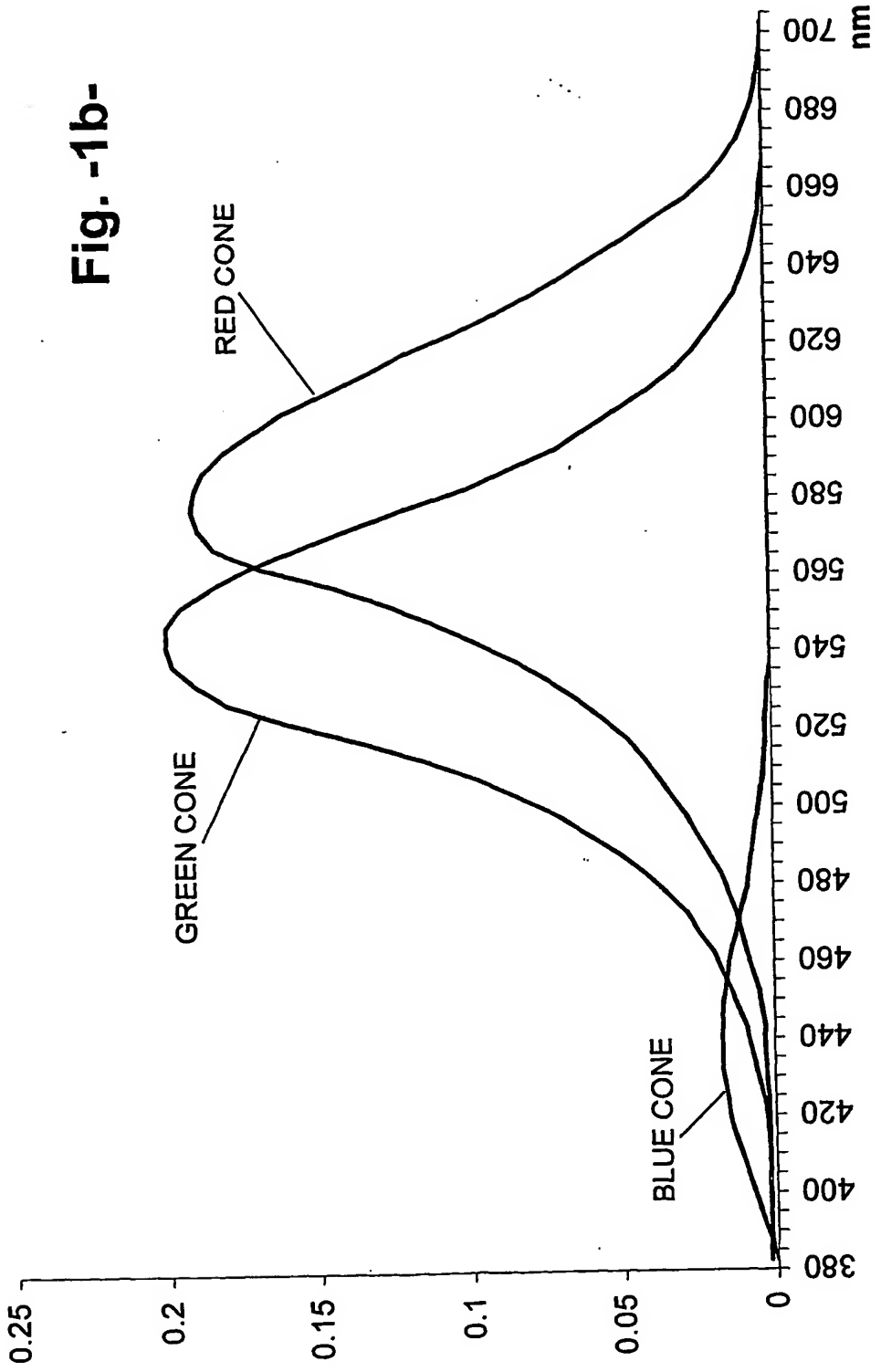
4
5
6
7
8

Fig. -1b-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GREEN CONE
BLUE CONE
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660
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nm

Fig. -2-

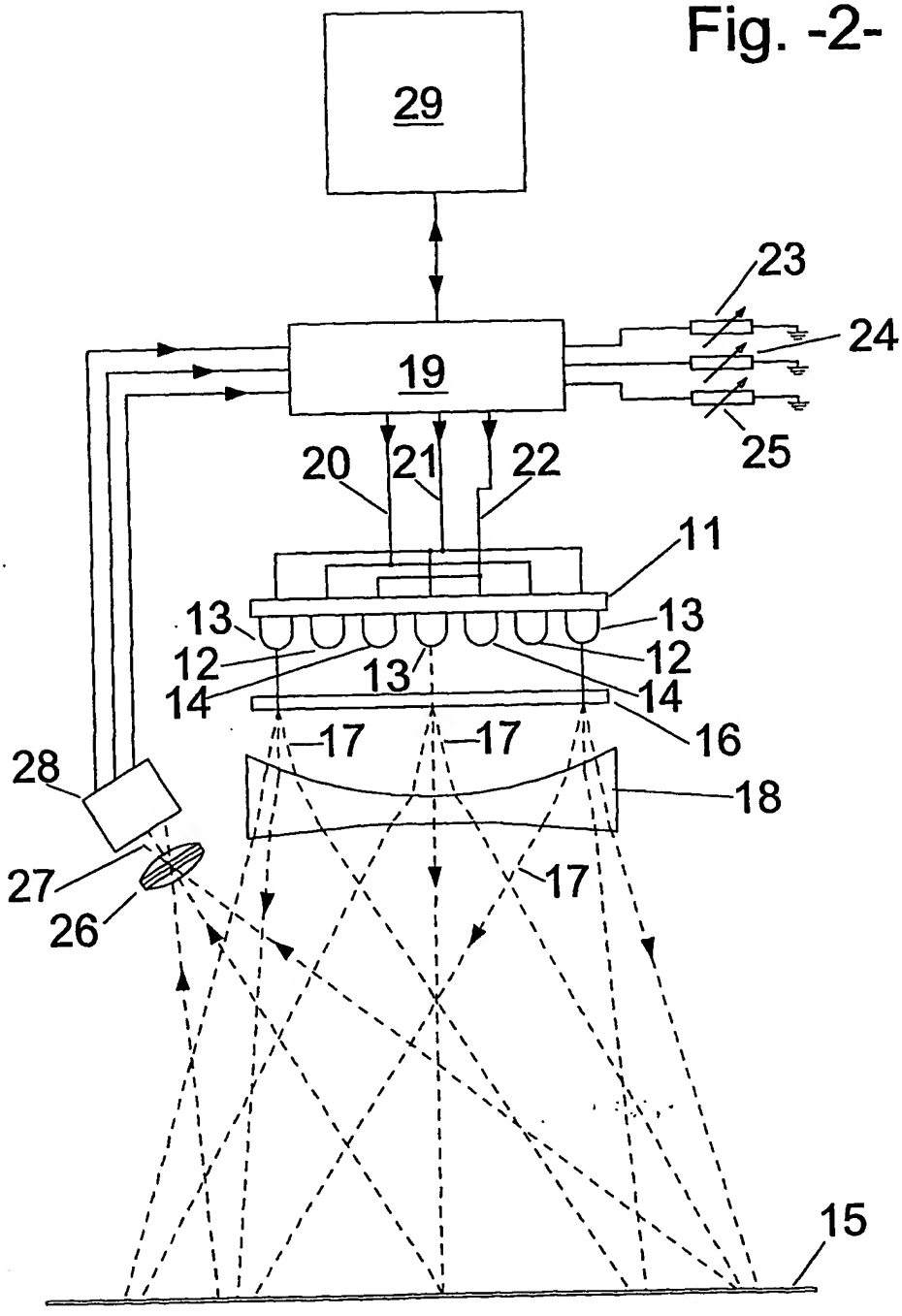
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Fig. -3-

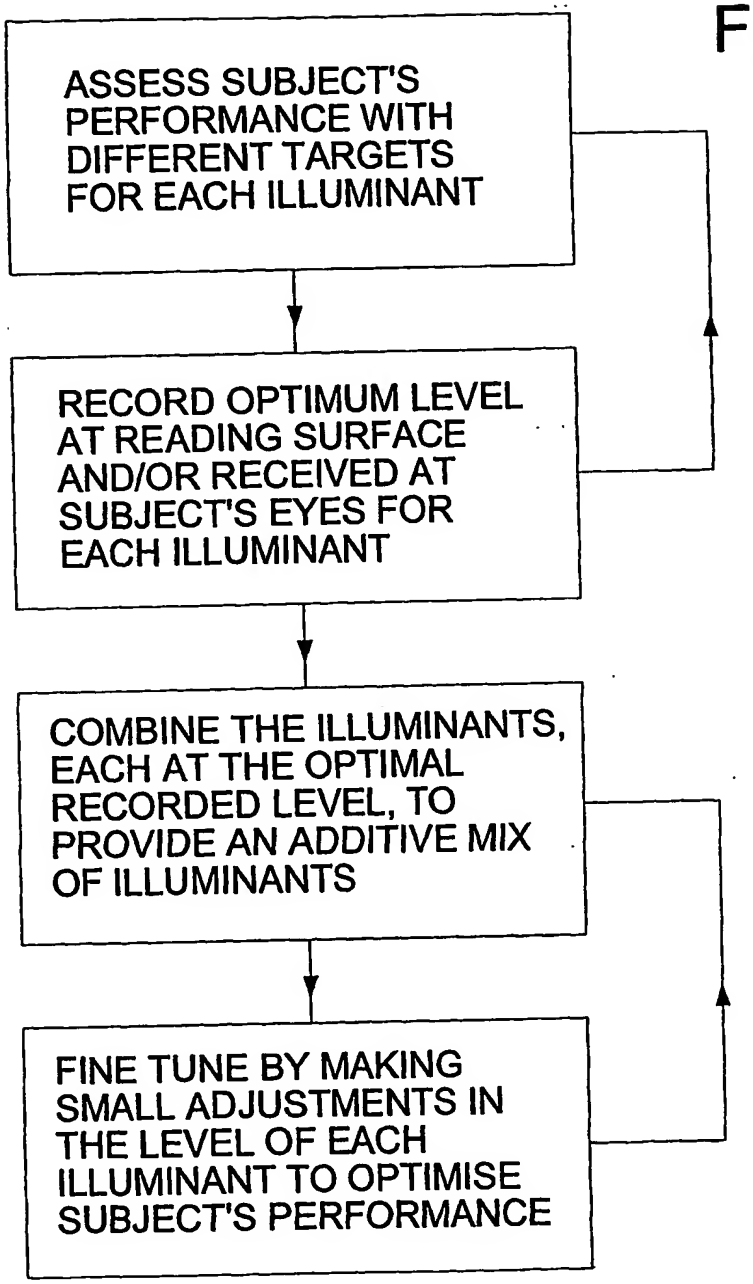
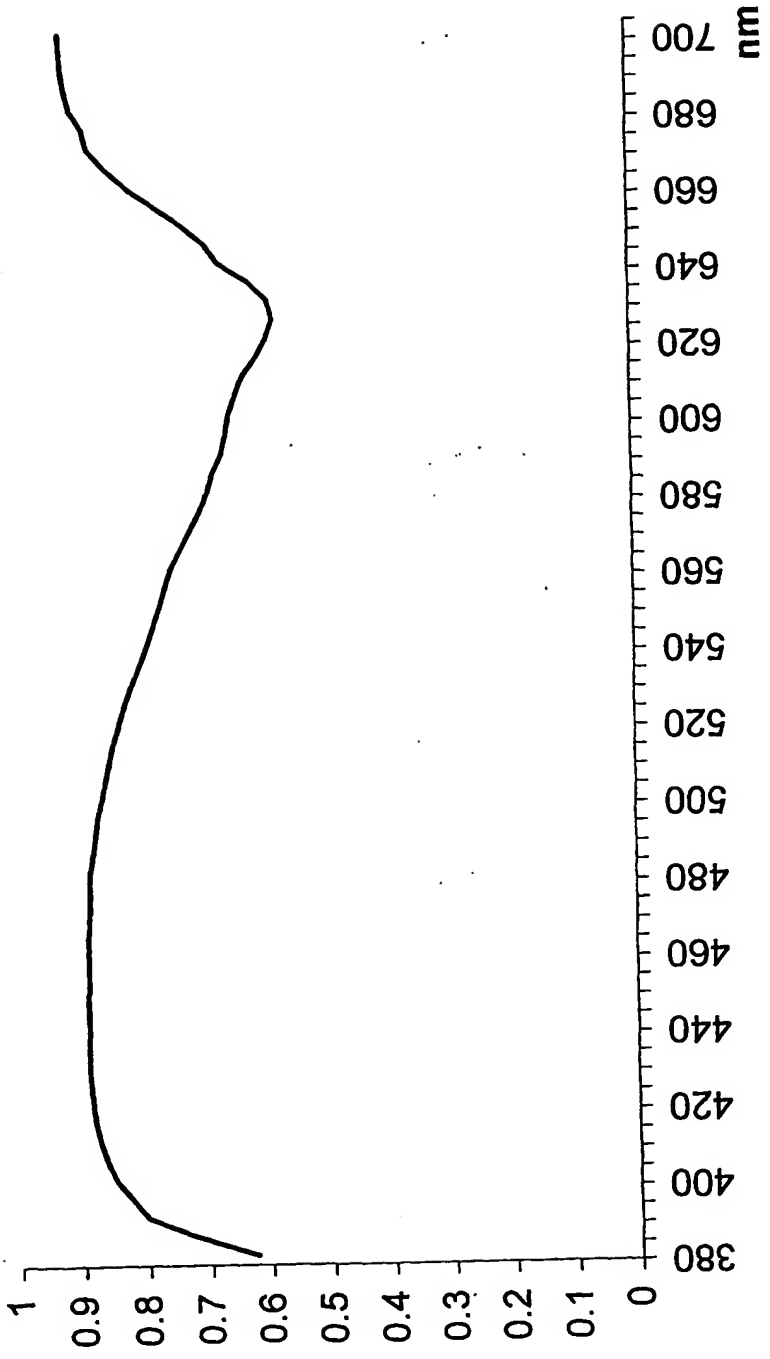

ASSESS SUBJECT'S PERFORMANCE WITH DIFFERENT TARGETS FOR EACH ILLUMINANT
RECORD OPTIMUM LEVEL AT READING SURFACE AND/OR RECEIVED AT SUBJECT'S EYES FOR EACH ILLUMINANT
COMBINE THE ILLUMINANTS, EACH AT THE OPTIMAL RECORDED LEVEL, TO PROVIDE AN ADDITIVE MIX OF ILLUMINANTS
FINE TUNE BY MAKING SMALL ADJUSTMENTS IN THE LEVEL OF EACH ILLUMINANT TO OPTIMISE SUBJECT'S PERFORMANCE

Fig. -4-


nm
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660
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620
600
580
560
540
520
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480
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400
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0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

INTERNATIONAL SEARCH REPORT

ional Application No
PCT/GB 01/05544

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 A61N5/06 A61B3/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 A61N A61B F21S G02C G01J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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A		5,13,16
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A	US 4 961 640 A (IRLEN HELEN L) 9 October 1990 (1990-10-09) column 3, line 58 -column 4, line 37	16

-/—

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
17 April 2002	23/04/2002

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Petter, E

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 01/05544

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 1-13

   Apparatus comprising a plurality of light sources

2. Claims: 16-19

   Method for simulating a filter

INTERNATIONAL SEARCH REPORT

Information on patent family members

I tional Application No
PCT/GB 01/05544

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
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